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THE CHOSEN ELECTRICAL PROPERTIES OF THIN LAYER AND THEIR SIGNIFICANCE STUDY

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Abstract

The paper is oriented on the planned factorial experiment, the measurement of electrical parameters of thin films SiO_2 and TiO_2 which were prepared by dipcoating technology, specifically by sol – gel method. The films of SiO_2, respectively TiO_2 were coated on the basic ceramics substratum of Al_2O_3. The thin films were tested under humidity environs and frequency depencency changes. These results of impedance and phase angle were verified by analysis of statistical significance through calculated Fisher criteria; with estimation of the three input factors.

Abstrakt

Článok sa orientuje na plánovaný faktorový experiment, meranie elektrických vlastností tenkých vrstiev SiO_2 a TiO_2 ktoré boli pripravené technológiou "dipcoating", konkrétne pomocou sol-gél metódy. Vrstvy SiO_2 respekívne TiO_2 boli nanášané na základný keramický substrát – podložku z Al_2O_3. Tenké vrstvy boli testované pri zmene vlhkosti a frekvencie. Výsledky impedancie a fázového uhla boli verifikované analýzou štatistickej významnosti prostrednícvom výpočtu Fisherovho kritéria so stanovenými tromi vstupnými faktormi.

Key words: thin films, relative humidity (RH), electric parameters

1. Introduction

Nowadays are the methods of statistical planning of experiments augmented into whole areas of science and technics. The using of statistical method of planned experiments has opposite the clasicall planning of experiments some advantages, to create the mathematical model of research dependency by realization of miminal number of experiments. The general content of this article is to declare, resp. confute the statistical significance of estimated factors in area of thin films and their measurements of electrical parameters like outputs.

By term of "planned experiment" we can explain continuosly and well knowing setup of choosen input parameters – so called factors. Full factor experiment and its three factor proposal will be estimating the adequating or nonadequating of this experimental. Linear model creation of planned experiment contents the matrix of planned experiment, realization of planning, coefficients estimation of model and statistical analysis of results.

For mathematical exlanation of processes and objects are used models, where the factors of the first degree presented isolated respectively product of several factors.

$$\hat{y} = b_0 + \sum_{j=1}^{k} b_j x_j \quad or \quad \hat{y} = b_0 + \sum_{j=1}^{k} b_j x_j + \sum_{j\langle g=1}^{k} b_{jg} x_j x_g + ...$$

Where the last elements indicate all possible double, triple, ..., products of factors. The coefficients of linear model are estimated from the experimental datas. Given experiment contens the finite number of attempts and makes it possible to obtain the choosen estimation of experiment. Their precision and safety are dependent of their selection and its nesesarry to make the statistical checking.

2. Solution

The present solution is in the basic step – matrix detailing creation.

$$[X] = \begin{bmatrix} x_0 & x_1 & x_2 & x_3 & x_1x_2 & x_2x_3 & x_1x_3 \\ 1 & -1 & -1 & -1 & +1 & +1 & +1 \\ 1 & +1 & -1 & -1 & -1 & +1 & -1 \\ 1 & -1 & +1 & -1 & -1 & -1 & +1 \\ +1 & +1 & +1 & -1 & +1 & -1 & -1 \\ 1 & -1 & -1 & +1 & +1 & -1 & -1 \\ 1 & +1 & -1 & +1 & -1 & -1 & +1 \\ 1 & -1 & +1 & +1 & -1 & +1 & -1 \\ 1 & +1 & +1 & +1 & +1 & +1 & +1 \end{bmatrix}$$

Fig. 1 Schematic representation the matrix of planned experiment.

The three factor planned experiment deals with three specified factor, which are able to induce the real output. Our imagination of quite rapidly changes was in factor proposal like type of coated thin film, frequency and humidity environ.

Table 1-Estimated factors, their coded and real values

FACTORS	CODED VALUE	CODES		
		LOWER BOUND	MIDDLE	UPPER BOUND
TYPE OF THIN FILM	X1	SIO_2	-	TIO_2
HUMIDITY ENVIRON [%]	X2	0,13	24.35	48.7
FREQUENCY [HZ]	X3	0	5E5	1E6

Measurement was realized by humidity environs via range 0, 13% to 48, 75 % of relative humidity (RH) and frequency range of 50 Hz to 1MHz for two various systems of thin films.

3. Coefficients estimation

Statistical evaluation consists for impedance and phase angle analysis. The main goal is to obtain the adequate or nonadequate of choosen model with estimated factors.

Variation of repetition (VR) is estimed by following formula:

$$S^2(y) = S_B^2 = \frac{1}{8}.\sum S_i^2 = \frac{1}{8}.2{,}165.10^{13} = 2{,}7062.10^{12}$$

	S^2 (IMPEDANCE – I)	S^2 (PHASE ANGLE – PA)
CALCULATED VALUE OF VR	$2{,}7062 \cdot 10^{12}$	308,70455

Degree of freedom :

$$k_B = N.(k-1) = 8.(3-1) = 16$$

Error analyse (EA):

$$\bar{S}(y) = \sqrt{S^2(y)} = \sqrt{2{,}7062.10^{12}} = 1{,}6450.10^6$$

	S^2 (IMPEDANCE – I)	S^2 (PHASE ANGLE – PA)
CALCULATED VALUE OF EA	$1{,}6450 \cdot 10^6$	17,56999

Adequacy:

$$\hat{R} = \sqrt{1 - \frac{\sum_{i=1}^{N}(\bar{y}_i - \hat{y}_i)^2}{\sum_{i=1}^{N}(\bar{y}_i - \bar{\bar{y}})^2}} = \sqrt{1 - \frac{1{,}2986.10^9}{1{,}3600.10^{11}}} = 0{,}9952143$$

	S^2 (IMPEDANCE – I)	S^2 (PHASE ANGLE – PA)
CALCULATED VALUE OF ADEQUACY	0,9952143	0,999144564

Fisher´s criteria:

$$F = \frac{R^2.(N-(k+1))}{(1-R^2).(k-1)} = \frac{0{,}9952143^2.(8-(6+1))}{(1-0{,}9952143^2).(6-1)} = 20{,}745872$$

where k =6 table value (numer of possible status of factors)

	S^2 (IMPEDANCE – I)	S^2 (PHASE ANGLE – PA)
CALCULATED VALUE OF FISHER CRITERIA	20,745872	116,74952

Estimation of model adequacy:

The requirement of model adequacy:

If

$F > F_{kp}$ in this case is model adequate

Estimation of F_{kp} (table value)

$F_{0,05;1;16} = 4{,}49$

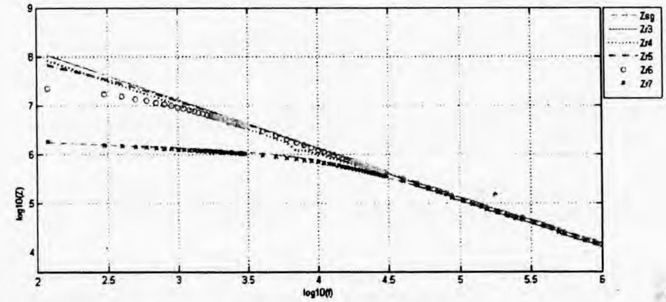

Fig. 2 Graphical representation of impedance vs. frequency for SiO_2 thin layer

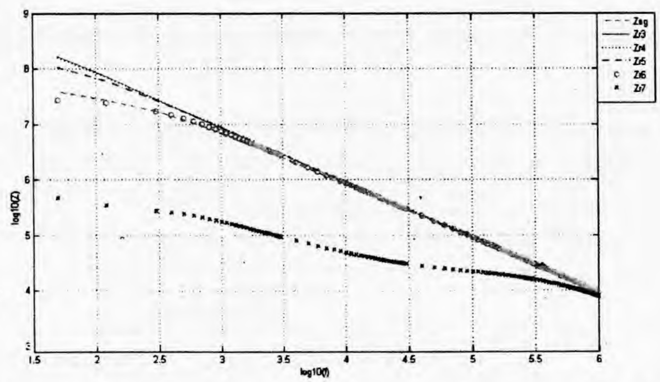

Fig. 3 Graphical representation of impedance vs. frequency for TiO_2 thin layer

4. Conclusion

The paper summarizes the significance influence of estimated factors in area of planned experimental, their calculation influence – which was compared with the estimated table value of Fisher criteria on 95% level of statistical significance. We suppose to allege that the factors – type of thin film, relative humidity environment and frequency range were chosen correct and have direct influence on measurement of impedance and phase angle of investigated thin film. This fact is also demonstrated on presented pictures.

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